Latest jet results from Tevatron

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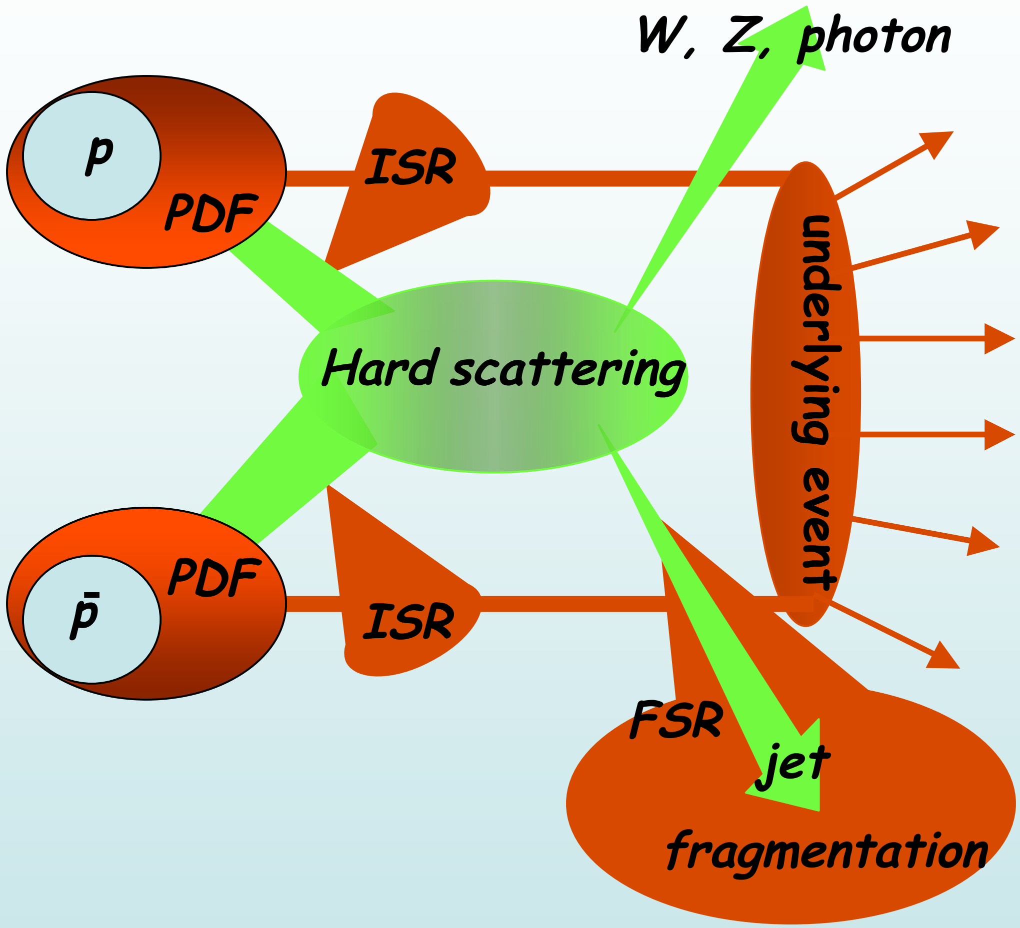
On behalf of CDF& D0 collaborations

XLI Rencontres de Moriond
QCD and High Energy hadronic Interactions
La Thuile - Italy, 18-24 March 2006

Jet Physics at 2TeV



Outline

This is only a selection of latest jet results from Tevatron!!!

Jet algorithms

Low P_T QCD

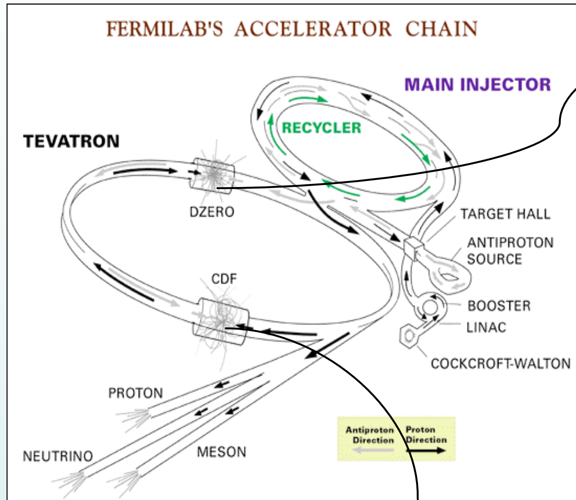
- Correlation of particle inside a jet & Fragmentation

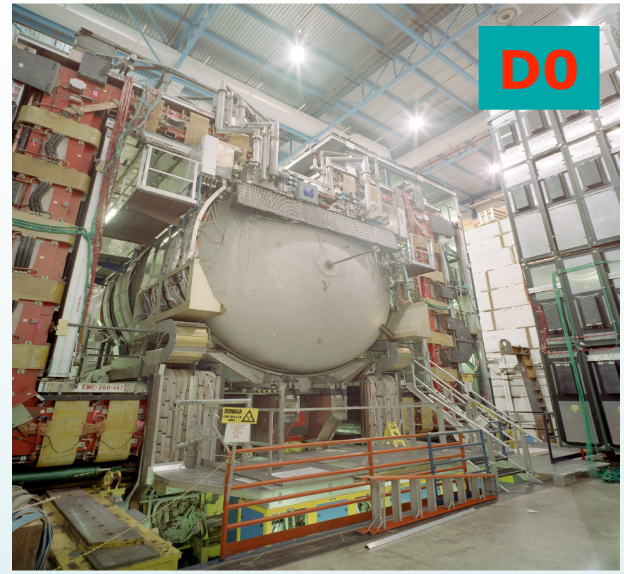
High P_T QCD

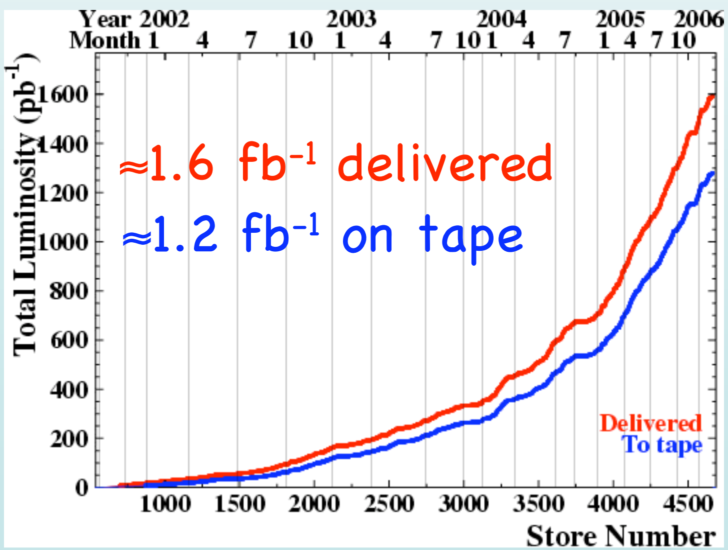
- Inclusive jet cross section:
  - ✓ Midpoint cone and K_T central jets
  - ✓ kT forward jets
    - o NLO comparison
- Heavy flavour jets:
  - ✓ μ-tagged jet cross section
  - ✓ b-tagged jets:
    - o Inclusive cross section
    - o Dijet correlation

The experimental environment

- ✓p-pbar collisions
- ✓$\sqrt{s}$=1.96 TeV (RunI 1.8)
- ✓36 bunches, 396 ns
- ✓peak Lum≥10^{32} [$cm^{-2}s^{-1}$]
- ✓≈ 25 pb^{-1}/week

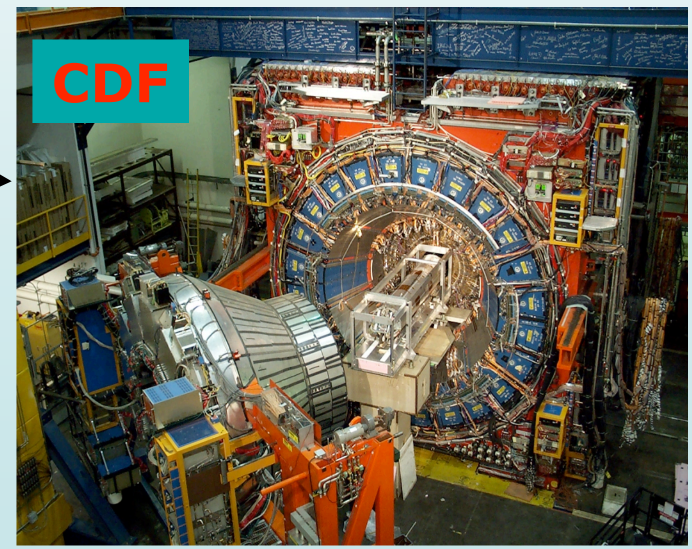






Both detectors performing well

analyses with 0.3-1.0 fb^{-1}

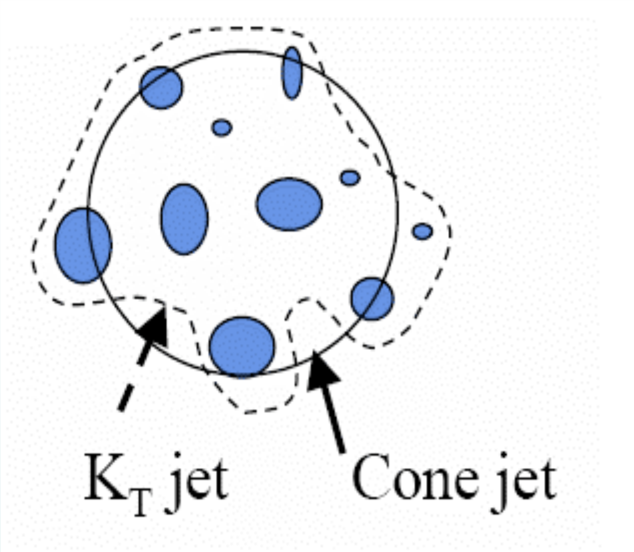


Jet algorithms

Jets are collimated sprays of hadrons originating from the hard scattering

Appropriate jet search algorithms are necessary to define/study hard physics and compare with theory

Different algorithms correspond to different observables and give different results!



K_T

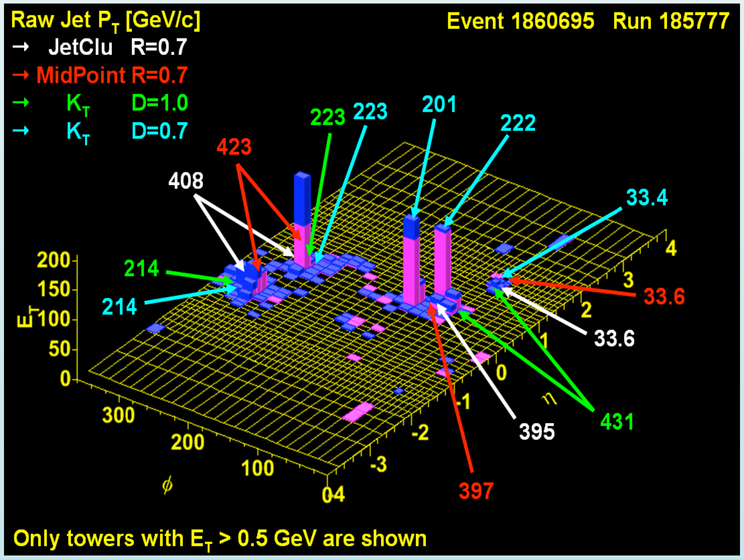
Cluster particle/towers

Based on their relative p_T

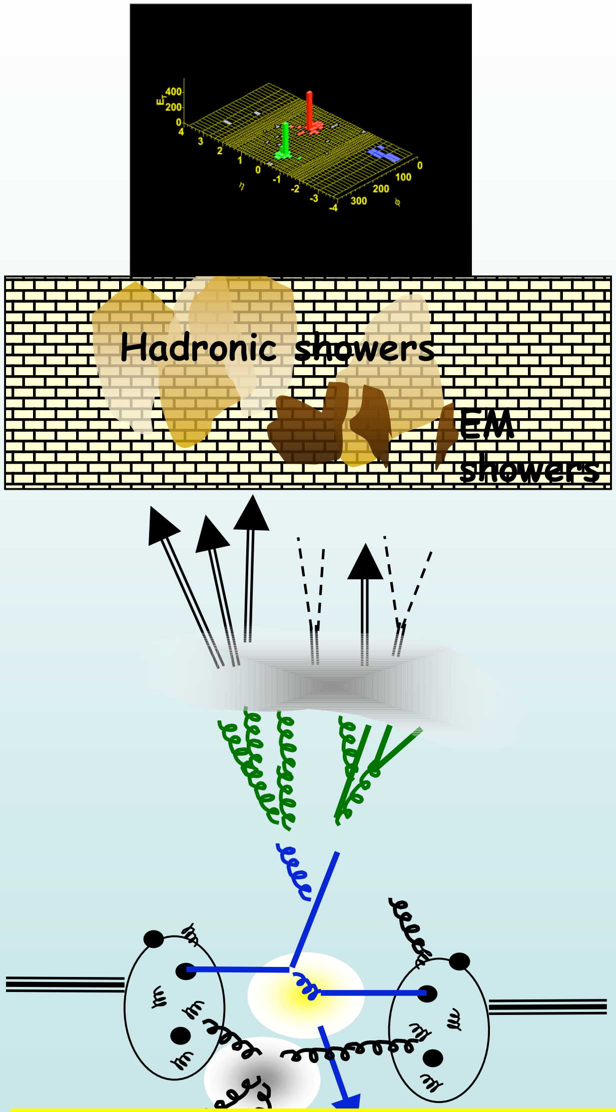
MidPoint(come)

Cluster particle/towers

Based on their proximity in the y-ϕ plane



Jet corrections



- ✓ Calorimeter jets: complex detector behavior
  - must correct for detector resolution and efficiency
  - must correct for pile-up interactions (up to ≈6 extra interactions)

- ✓ Hadron jets: model dependent correction
  - underlying event subtraction
  - remove fragmentation/hadronization effects
    - Monte Carlo model based
      - Need to be tuned on data!!! by using many different observables

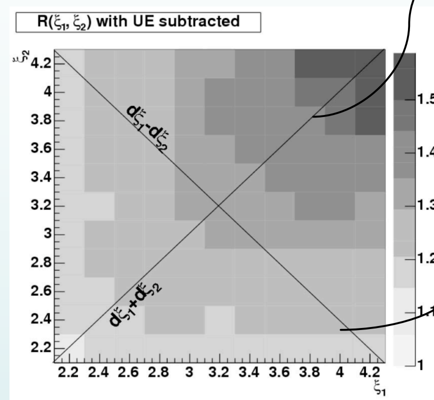
- ✓ Parton jets: model dependent correction
  - Gluon radiation, energy loss
    - Monte Carlo model based

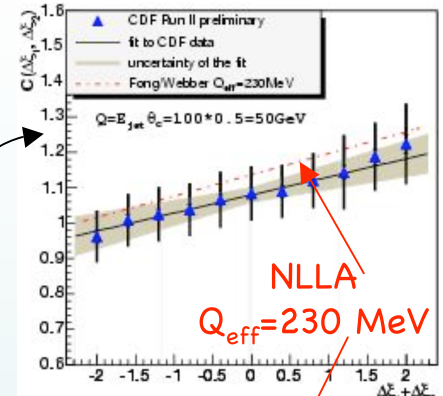
To compare with theory is important to have a good (phenomenological) simulation of soft physics: Underlying event, hadronization, fragmentation

Two particle momentum correlation & hadronization

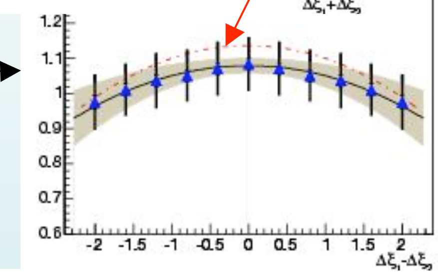
$$C(\xi_1,\xi_2)=\frac{\left(\frac{dn}{d\xi_1 d\xi_2}\right)}{\left(\frac{dn}{d\xi_1}\right)\left(\frac{dn}{d\xi_2}\right)}=c_0(E_{jet})+c_1(E_{jet})\bullet(\Delta\xi_1+\Delta\xi_2)+c_2(E_{jet})\bullet(\Delta\xi_1-\Delta\xi_2)^2$$

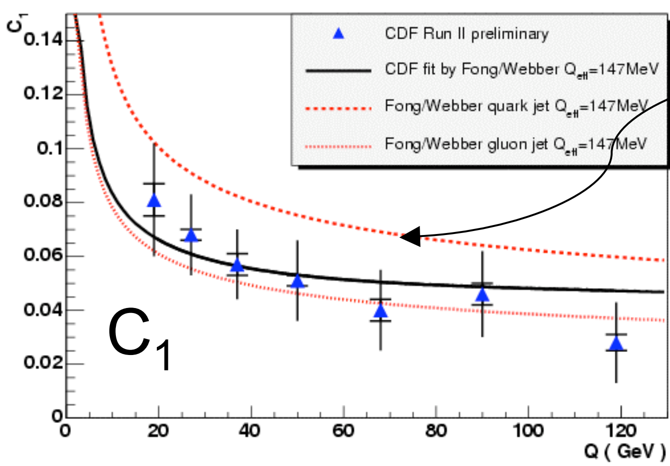
All particle pairs in cone 0.5 around the jet axis
$\xi=Ln(E_{jet}/P_{particle})$, $\Delta\xi=\xi-\xi^{At\ Max}$
$Q=E_{jet}\times\theta_{Cone}$; Q_{eff}= parton shower cutoff in the theory





NLLA
Q_{eff}=230 MeV



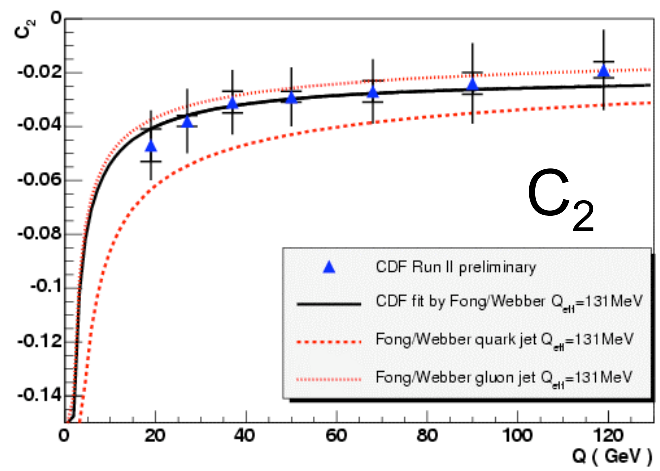


C_1

gluon jet
quark jet

$Q_{eff}\approx150$MeV

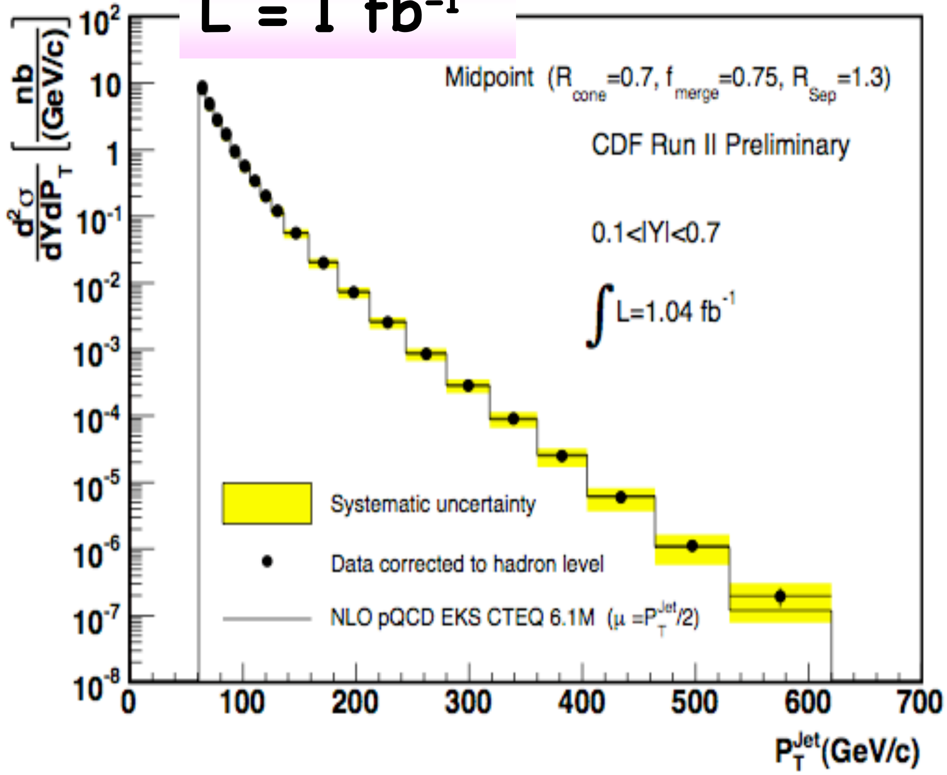
Local parton hadron duality



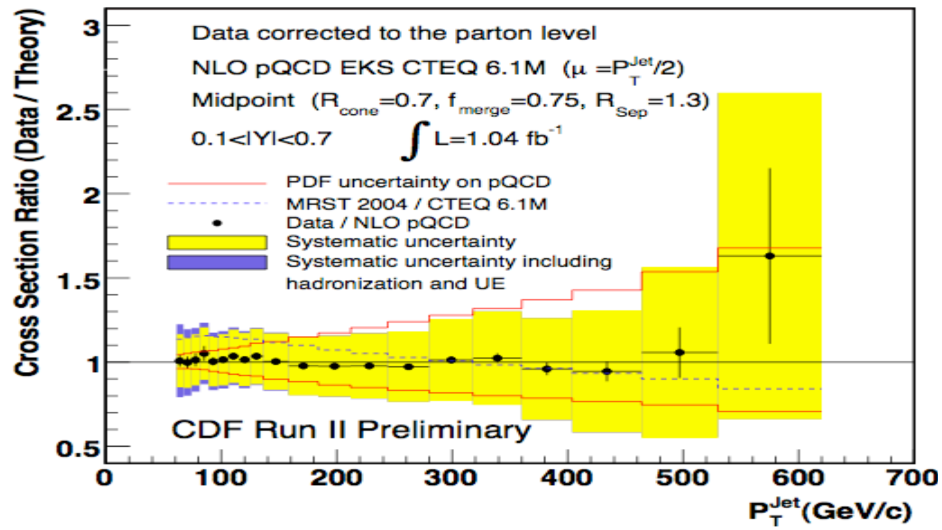
C_2

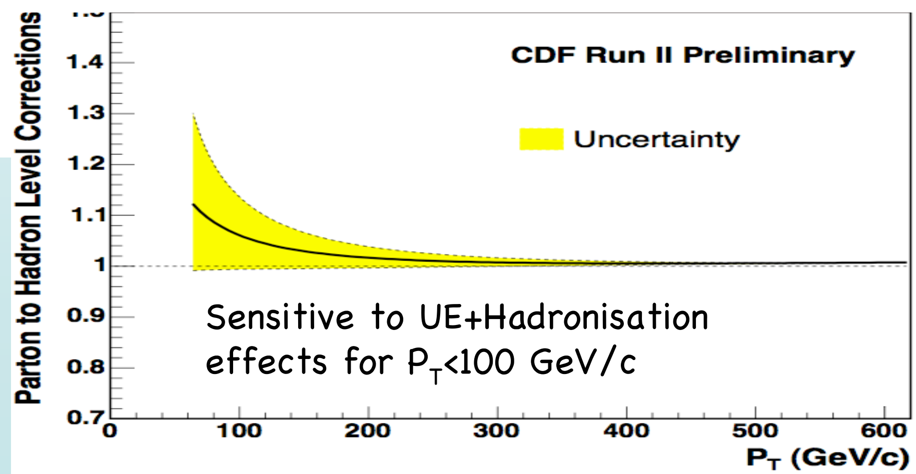
Inclusive Jet Cross Section-CDF (MidPoint algorithm R=0.7)

L = 1 fb^{-1}



Central jets: 0.1<|y^{jet}|< 0.7





Sensitive to UE+Hadronisation effects for P_T<100 GeV/c

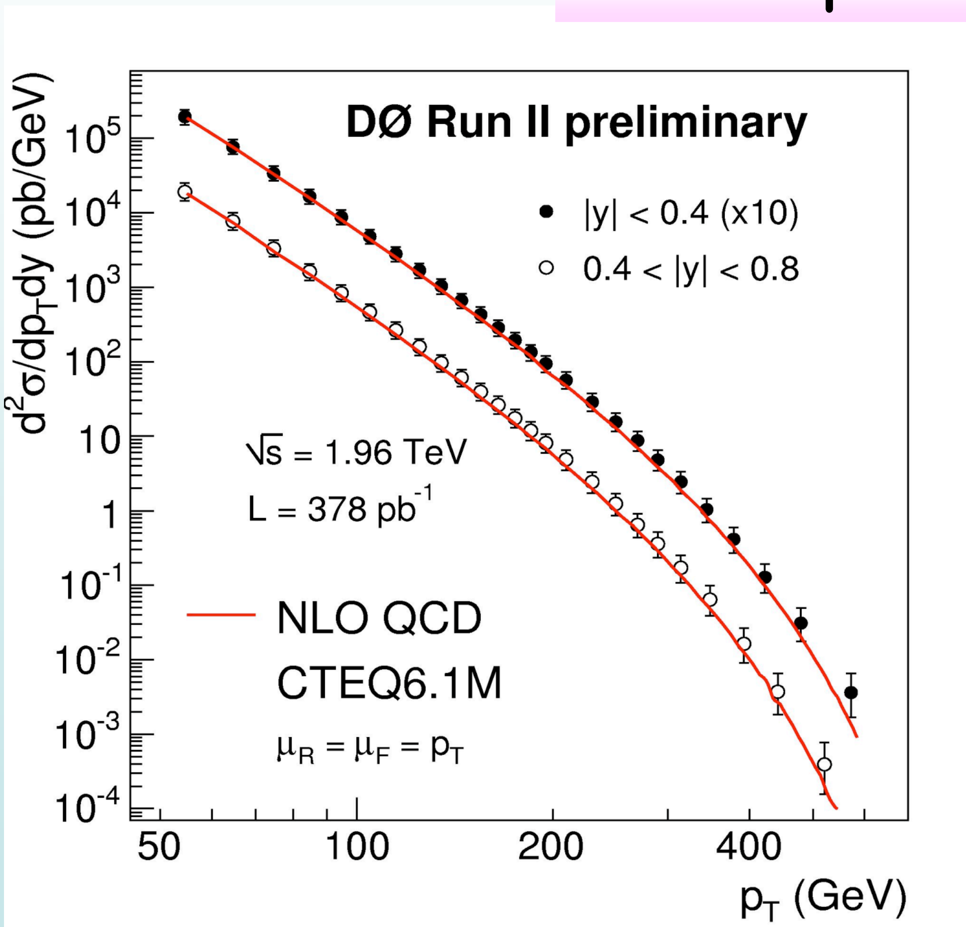
- ✓ Data dominated by Jet Energy Scale (JES) uncertainties (3%)
- ✓ NLO uncertainty due to high x gluon PDF

Good agreement with NLO CTEQ6.1M

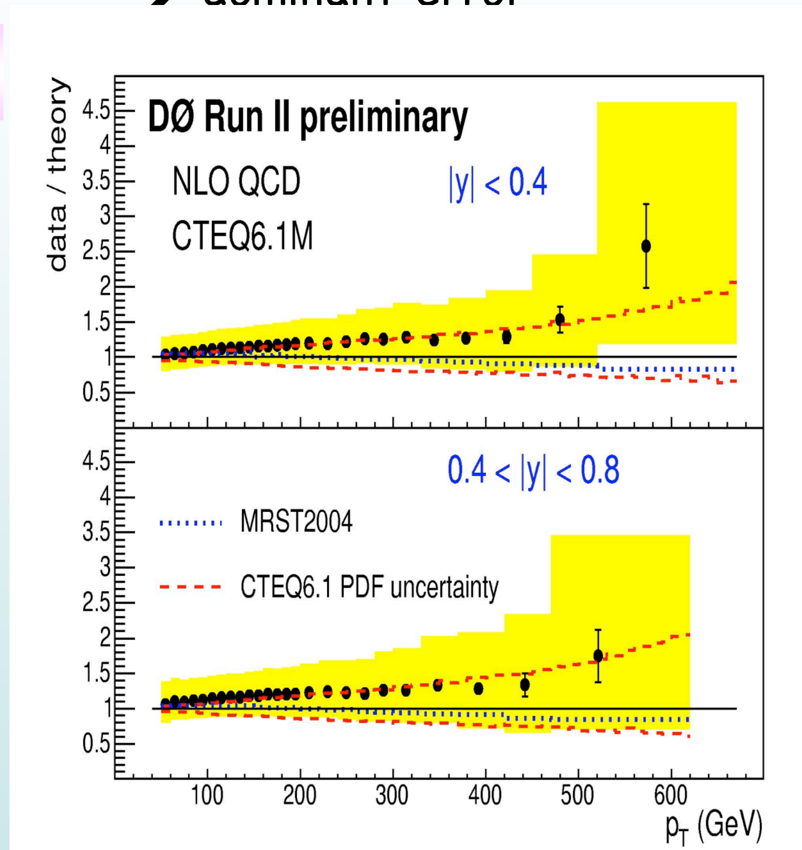
Inclusive Jet Cross Section-D0 (MidPoint algorithm R=0.7)

- 2 regions in rapidity explored
  - $|y^{jet}| < 0.4$
  - $0.4 < |y^{jet}| < 0.8$

L = 380 pb^{-1}



Jet energy scale uncertainty ➔ dominant error

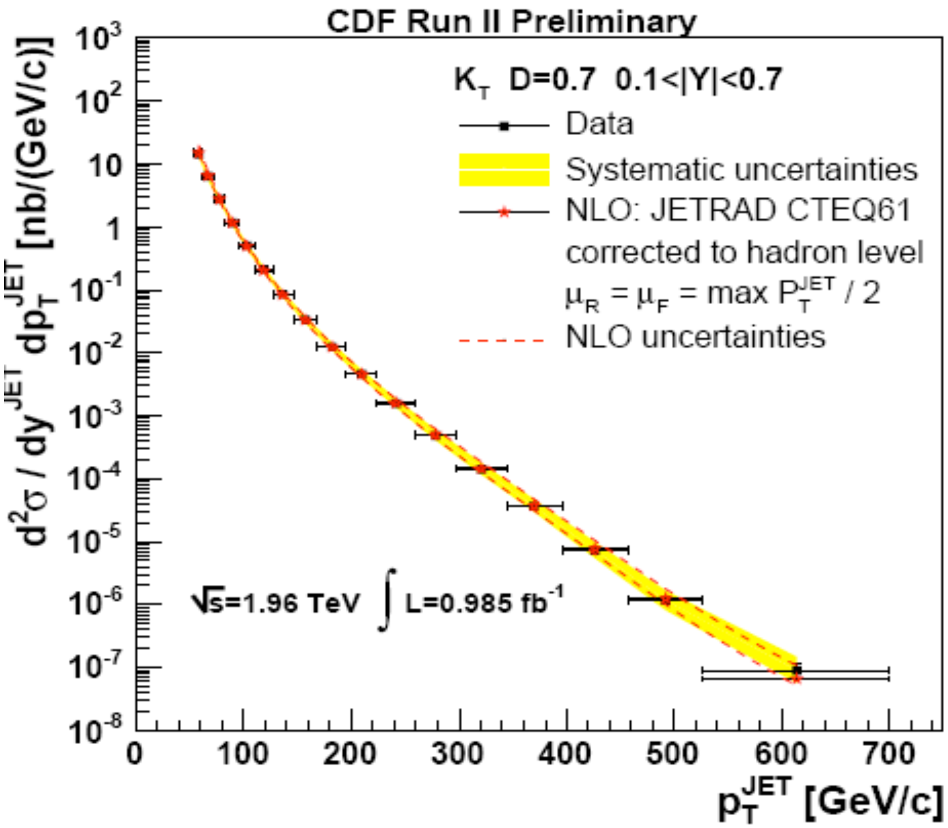


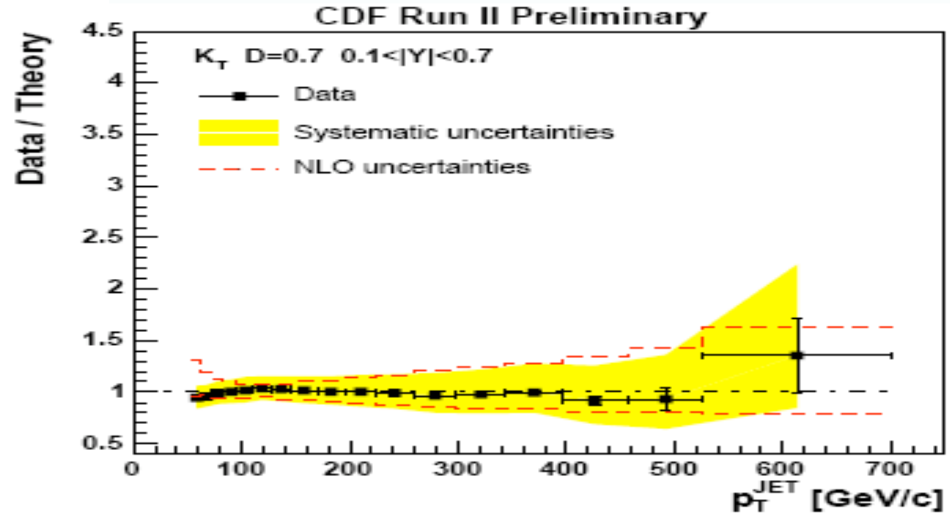
Good agreement with NLO prediction

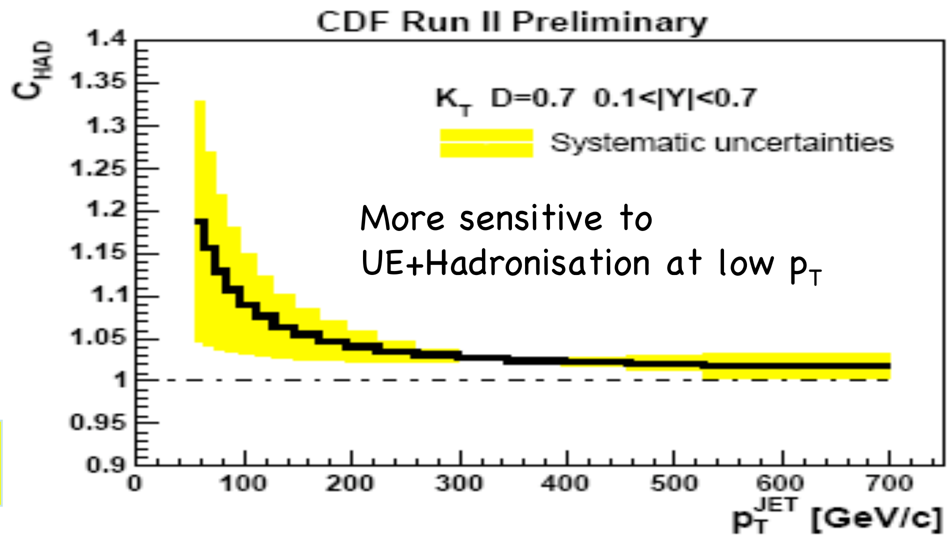
Inclusive Jet Cross Section-CDF
(K_T algorithm D=0.7)

L = 1 fb^{-1}

Central jets: $0.1<|y^{jet}|< 0.7$







More sensitive to UE+Hadronisation at low p_T

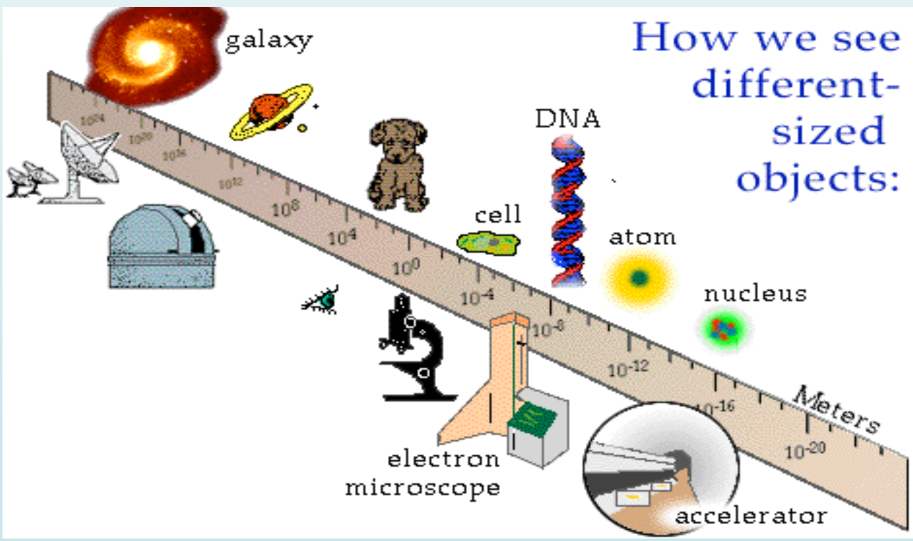
K_T works well in hadronic collisions

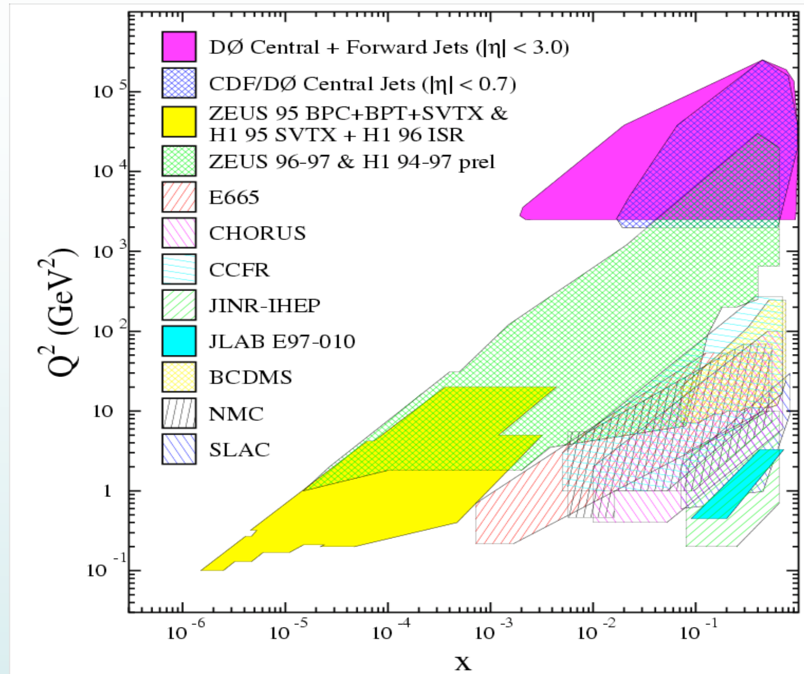
Good agreement with NLO CTEQ6.1M

Inclusive Jet Cross Section

Central jets

- Probes physics at small distances $\approx 10^{-19}$m
- Sensitive to PDF (gluon @ high-x)
- At high p_T dominated by jet energy systematic





Forward jets measurements: distinguish between new physics and PDF if any excess in the central region.
different jet $E_T \rightarrow$ different syst

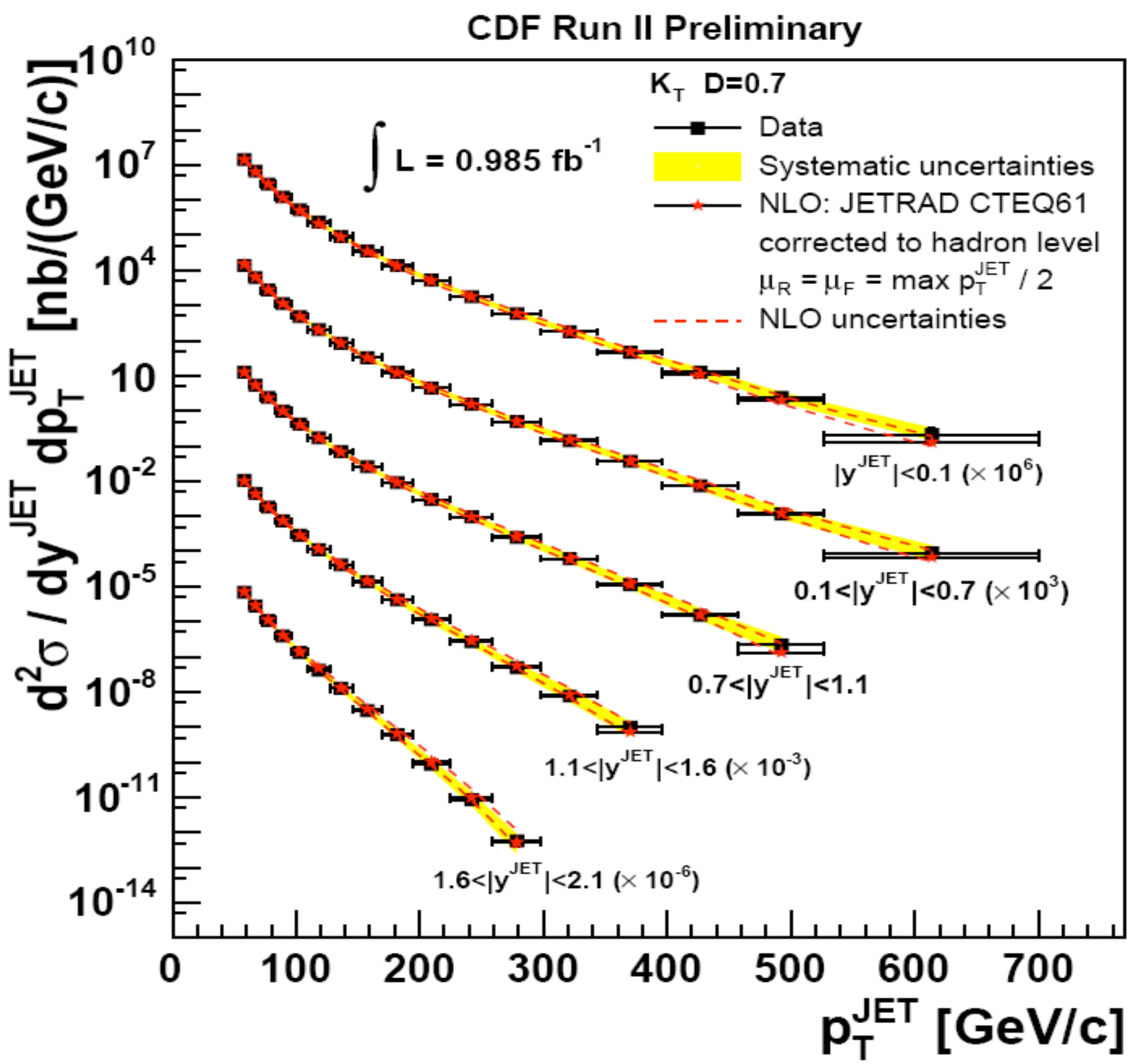
Forward Jet Cross Section-CDF
(K_T algorithm D=0.7)

L = 1 fb^{-1}

Five regions in jet rapidity explored (D=0.7):

- $|y^{jet}|<0.1$
- $0.1<|y^{jet}|<0.7$
- $0.7<|y^{jet}|<1.1$
- $1.1<|y^{jet}|<1.6$
- $1.6<|y^{jet}|<2.1$

Good agreement with the NLO pQCD for jets up to |Y|<2.1



μ-Tagged jets

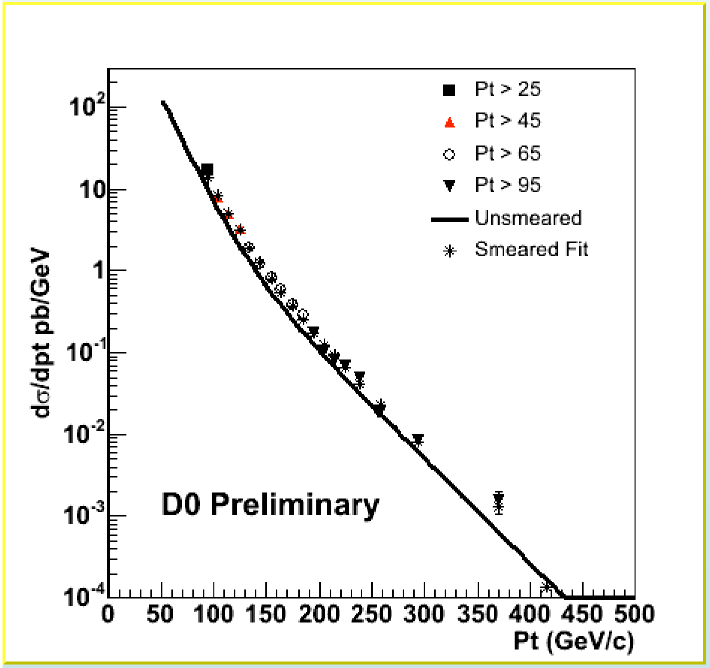
- jet containing heavy flavour often contain μ

  ⇒ search for μ enhances heavy flavour content

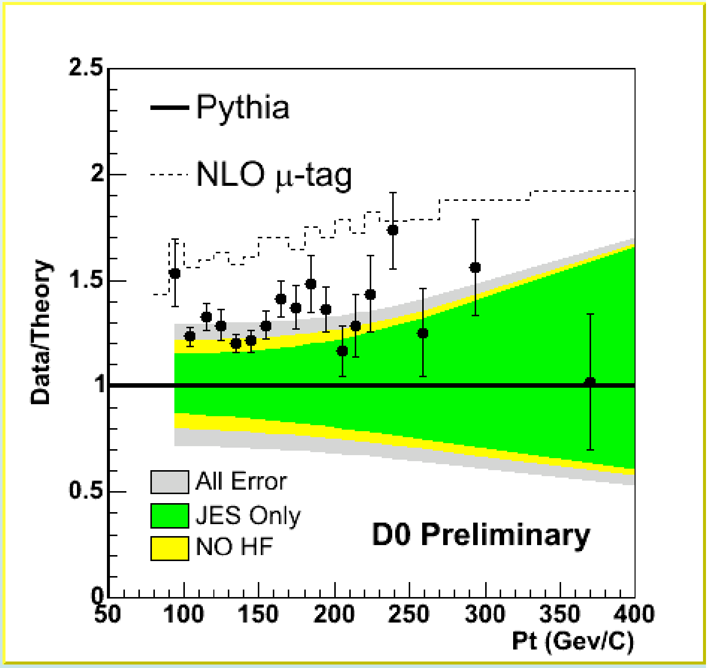
μ-Tagged jets cross section

L = 300 pb^{-1}

Data/Pyhtia ≈ 1.3 (flat)



- MidPoint algorithm cone R=0.5
- $|y^{jet}| < 0.5$
- require μ in R=0.5, P_T^{μ}>5GeV/c

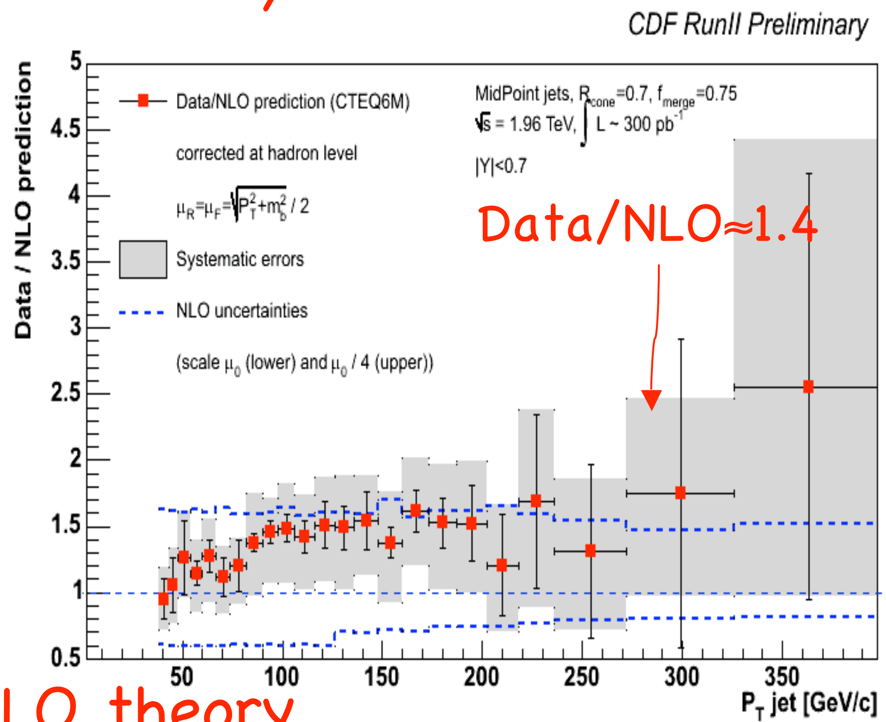


Inclusive bjet cross section

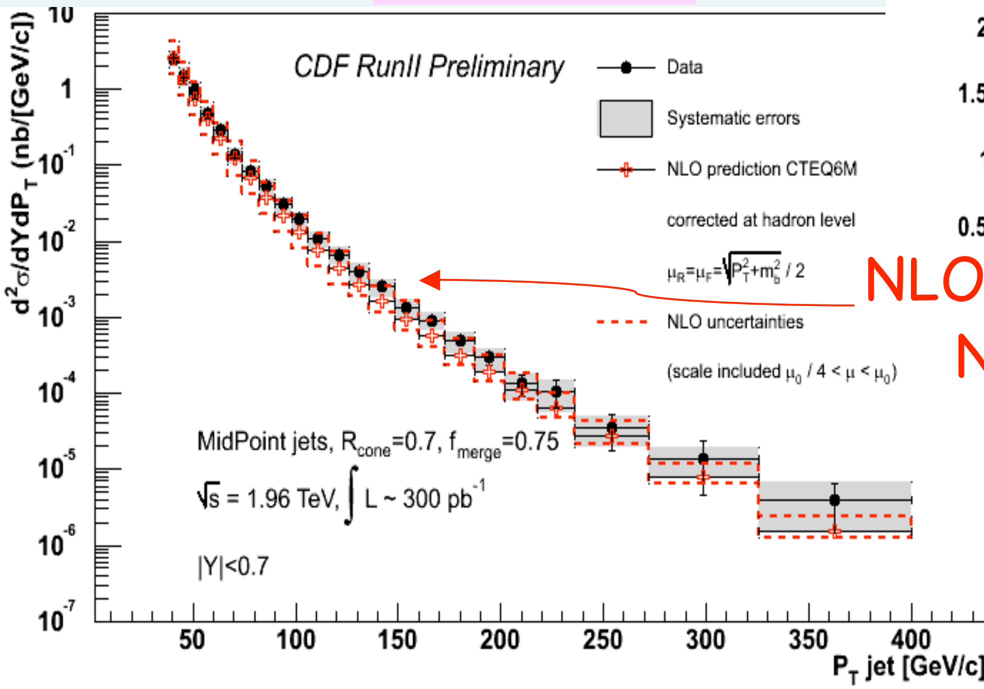
Reconstruct (silicon detector) secondary vertex from B hadron decays (b-tagging)

- ✓ Beauty production -> Test of pQCD
- ✓ MidPoint jets: R = 0.7, $|y^{jet}| < 0.7$
- ✓ Shape of secondary vertex mass used to extract b-fraction from data

$L = 300\ pb^{-1}$



Data/NLO≈1.4



NLO theory

NEW!

- ✓ More than 6 decades covered
- ✓ Data dominated by Jet Energy Scale and b-fraction uncertainties
- ✓ Uncertainties on NLO dominated by μ_R/μ_F scales

Summary

✓ Tevatron delivered More than 1.6 fb^{-1}

- Both CDF and D0 are performing well

✓ Rich QCD physcs program at Tevatron

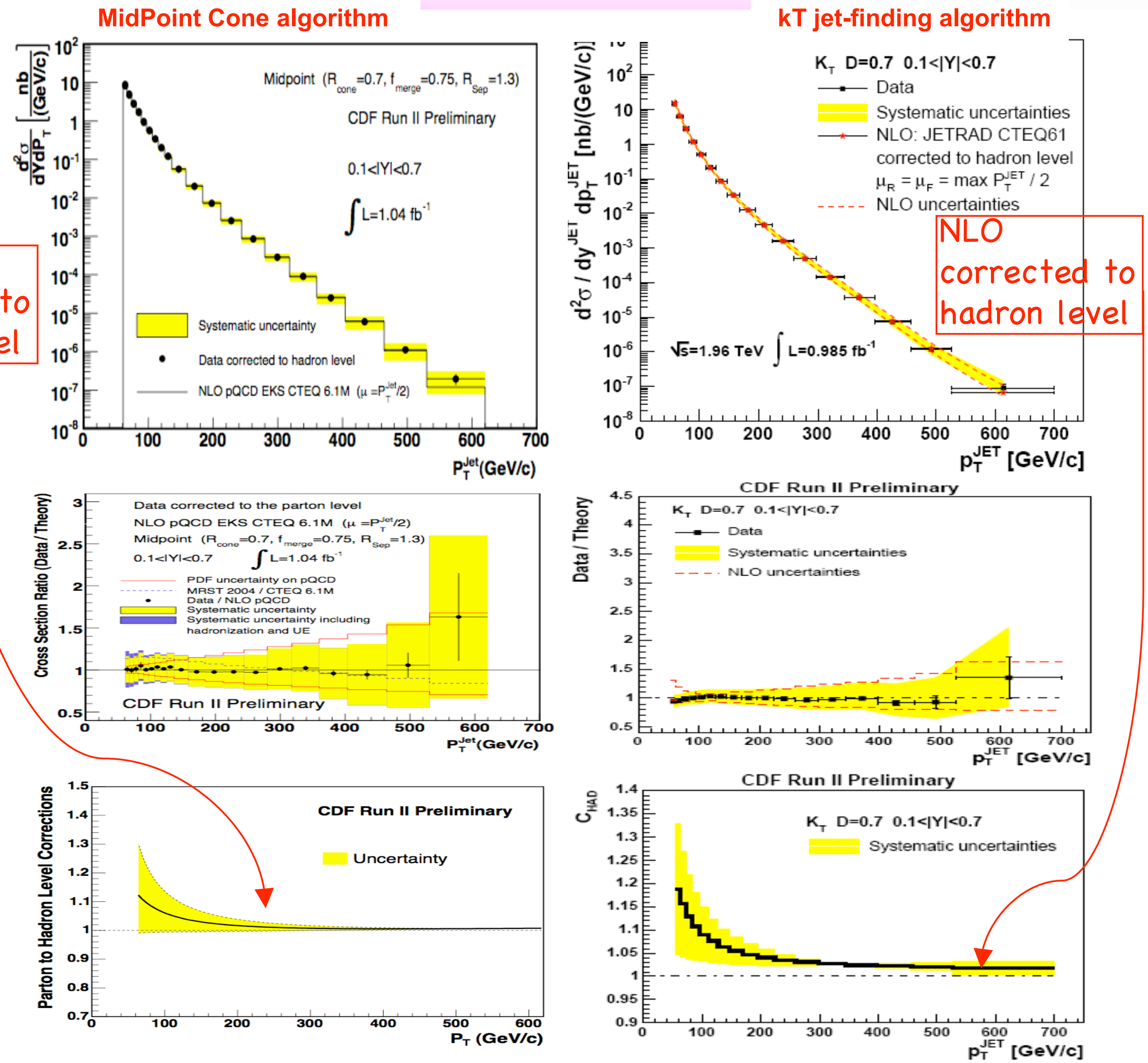
- Good progress in understanding soft p_T phyisics: underlying event, hadronization and particle correlation
- Theory (CTEQ61M) agrees with MidPoint and K_T jet cross section over 8 order of magnitude
- K_T jet algorithm works fine in hadronic collisions
- b-jet production measurements are self consistent

Backup Slides

Inclusive jet Cross Section

NEW L = 1 fb^{-1}

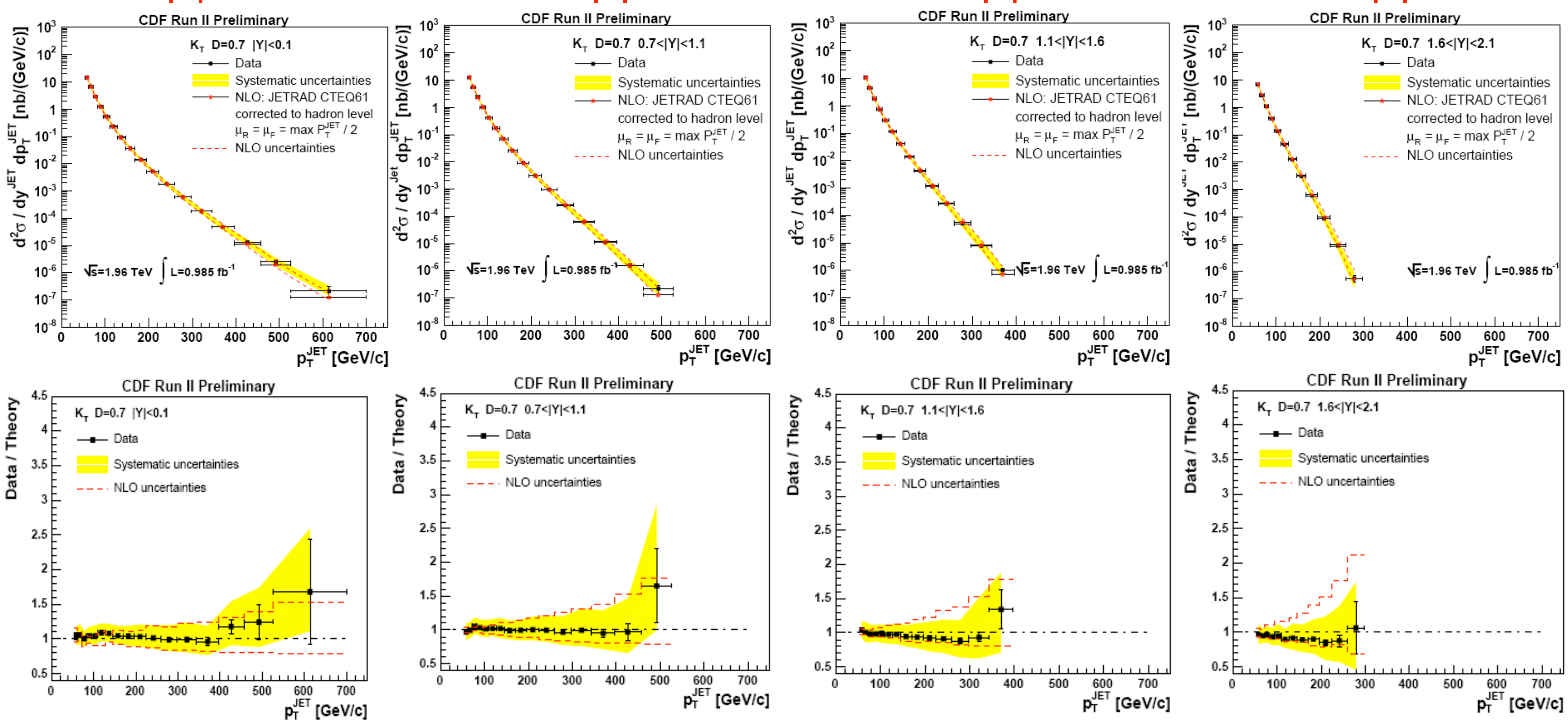
- ✓ Inclusive Jet
  - right: kT (D=0.7)
  - left: MidPoint (R=0.7)
  - Both central jets only: 0.1<|Y|<0.7
- ✓ Comparison to NLO:
  - both agree with NLO similar patterns in Data/Theory
- ✓ UE+Had Corrections
  - are phenomenological models, not a theory!
  - important for P_T<100
  - k_T algorithm is twice more sensitive



Inclusive jet K_T

NEW L = 1 fb^{-1}

|Y|<0.1   0.7<|Y|<1.1   1.1<|Y|<1.6   1.6<|Y|<2.1



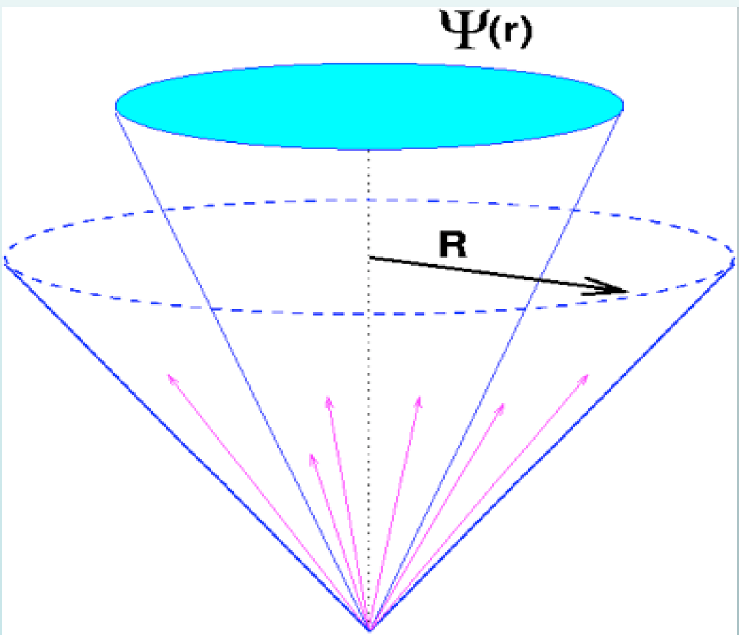
Good agreement with Theory @ NLO!!!

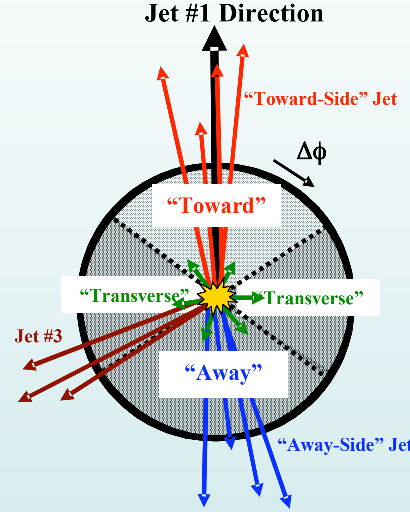
K_T algorithm works in hadron-hadron collisions!!!

Underlying event and Hadronization

To compare with theory is important to have a good (phenomenological) simulation of soft physics: Underlying event, hadronization, fragmentation

Jet shape inclusive jet production (CDF):
Phys. Rev. D 71, 112002 (2005)





Pythia Tune A

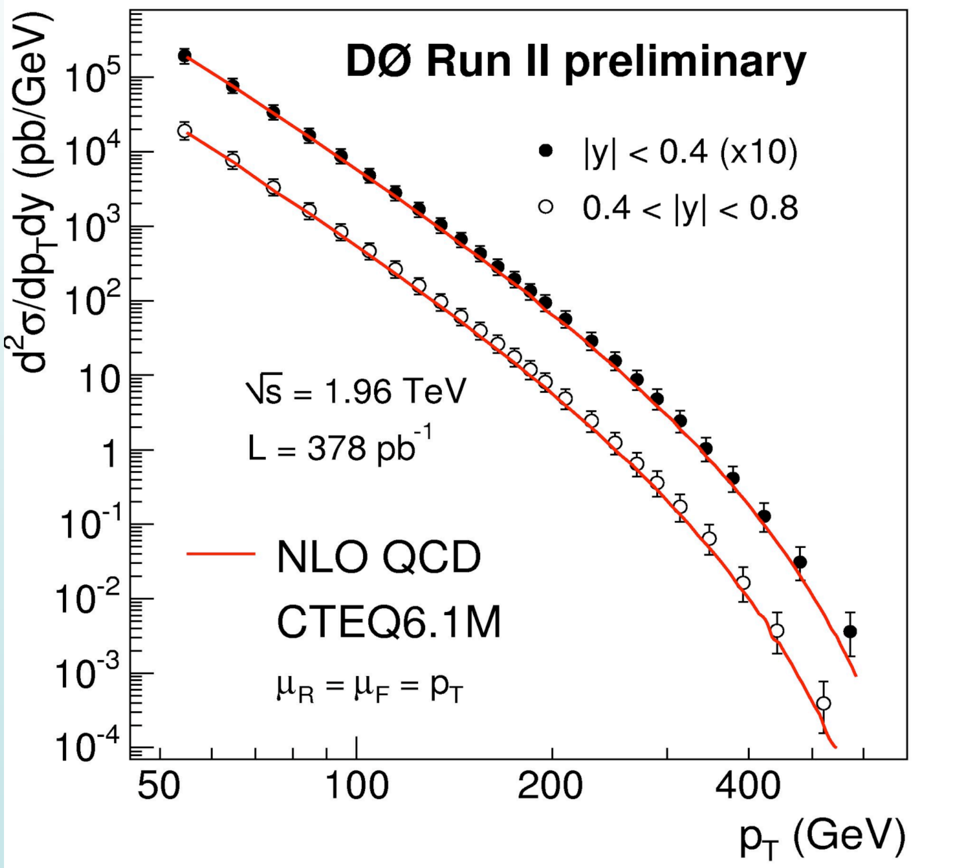
CDF

Shower Monte Carlo can be tuned to reproduce data behavior

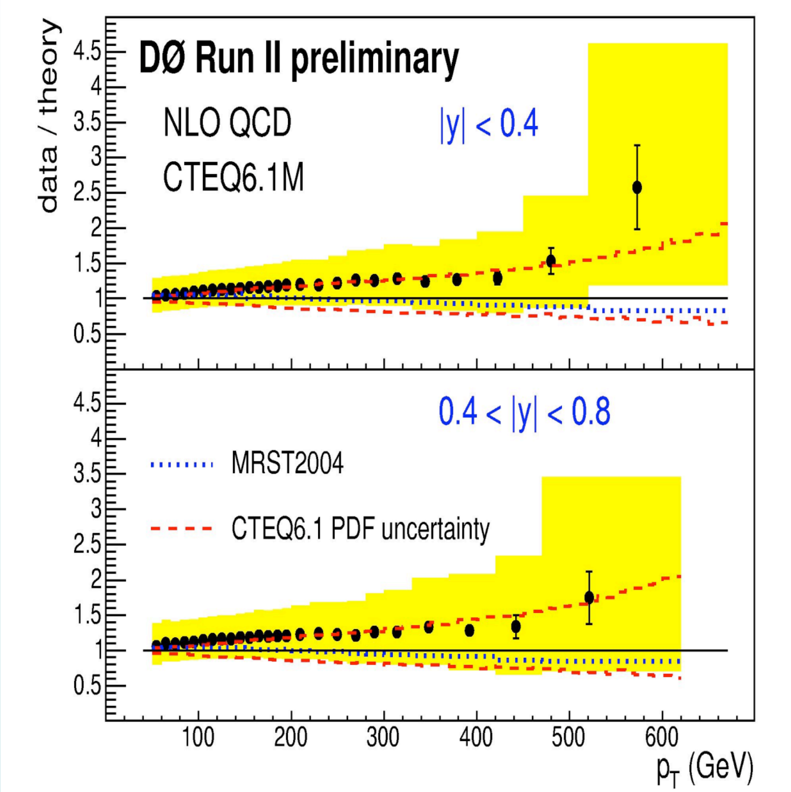
Inclusive jet (D0)

- MidPoint algorithm R = 0.7
- 2 regions in rapidity explored
  - $|y^{jet}| < 0.4$
  - $0.4 < |y^{jet}| < 0.8$

L = 380 pb^{-1}



Jet energy scale uncertainty ➔ dominant error

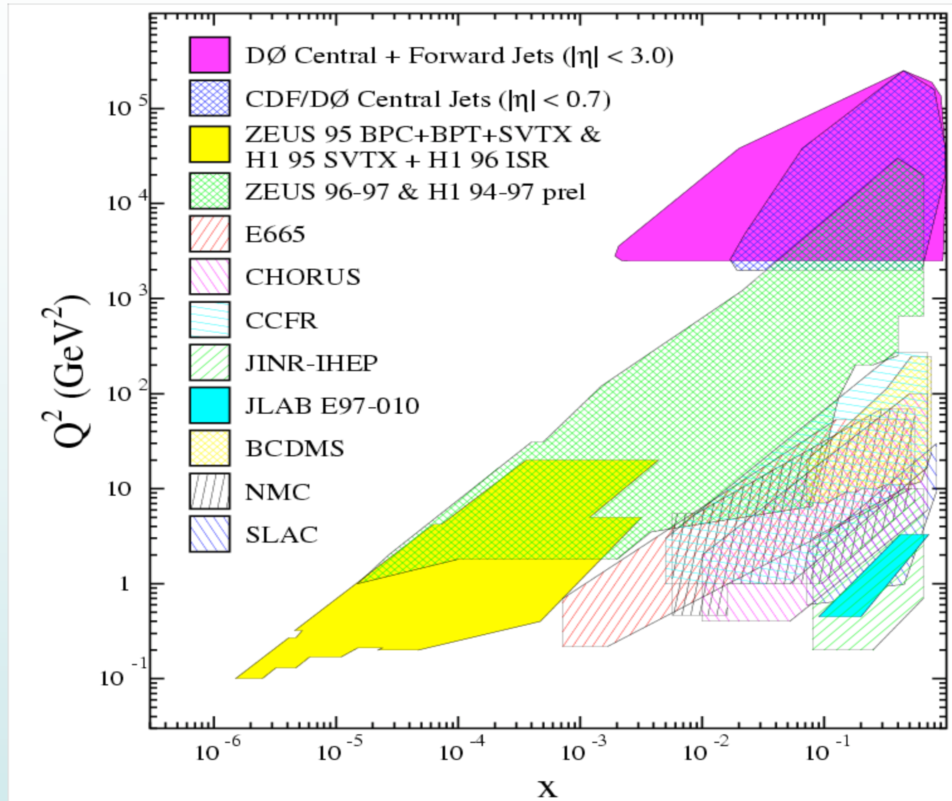


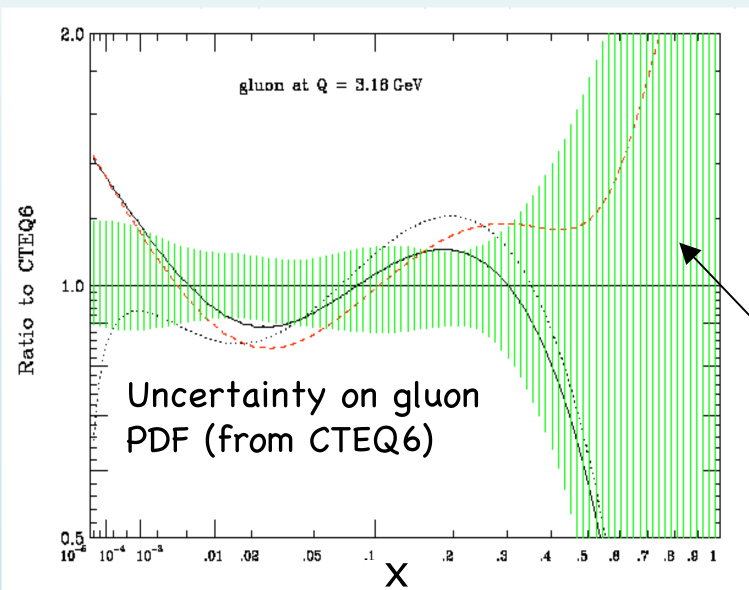
Good agreement with NLO prediction

Gluon PDF at high-x

E.g. Forward jets measurements help to distinguish between new physics and PDF if any excess in the central region

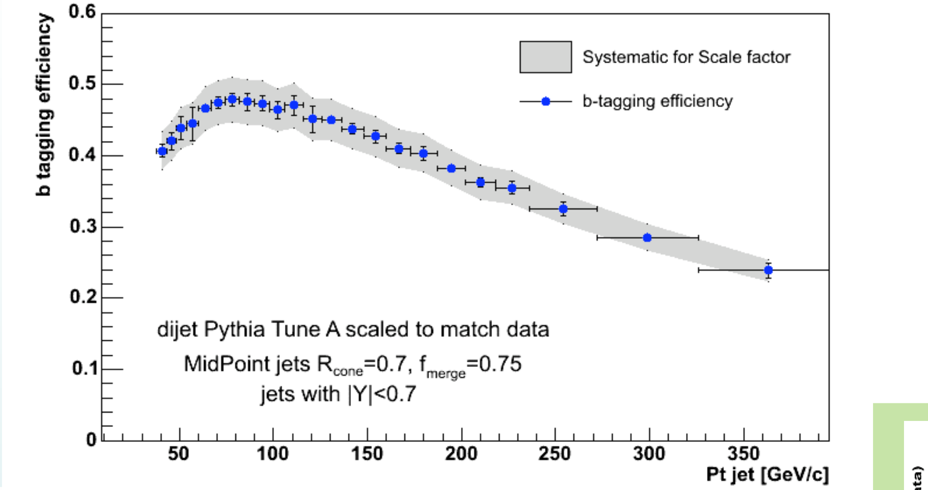
from Run I



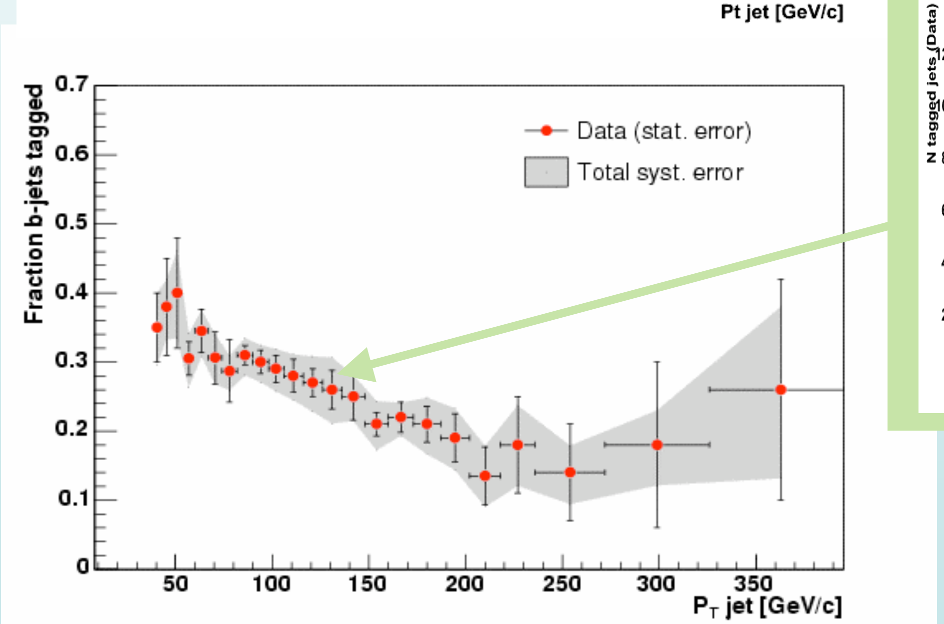


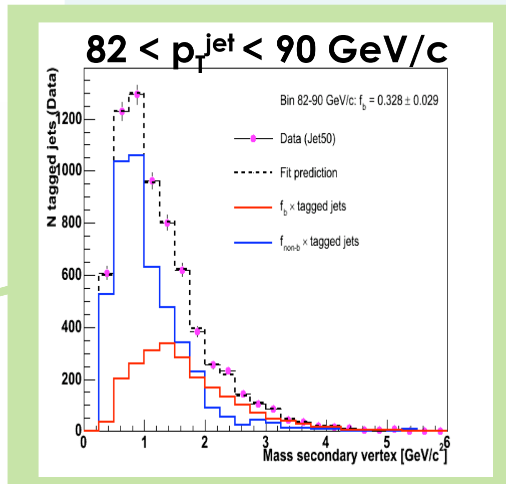
Big uncertainty for high-x gluon PDF

High P_T b-jet



Displaced tracks inside jet used to reconstruct secondary vertex from B hadron decays (b-tagging)



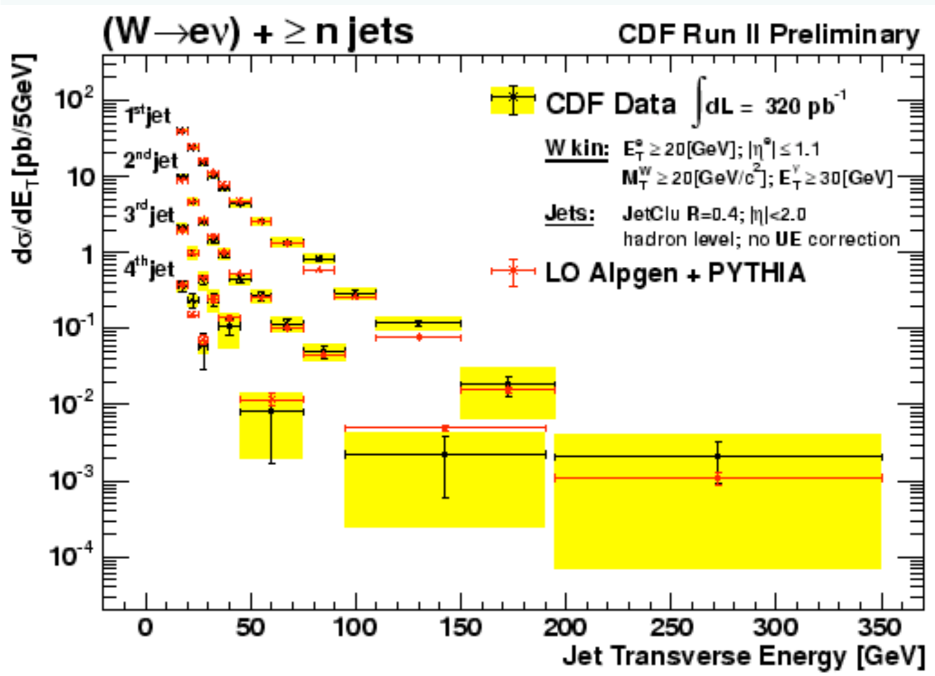


Extract fraction of b-tagged jets from data:

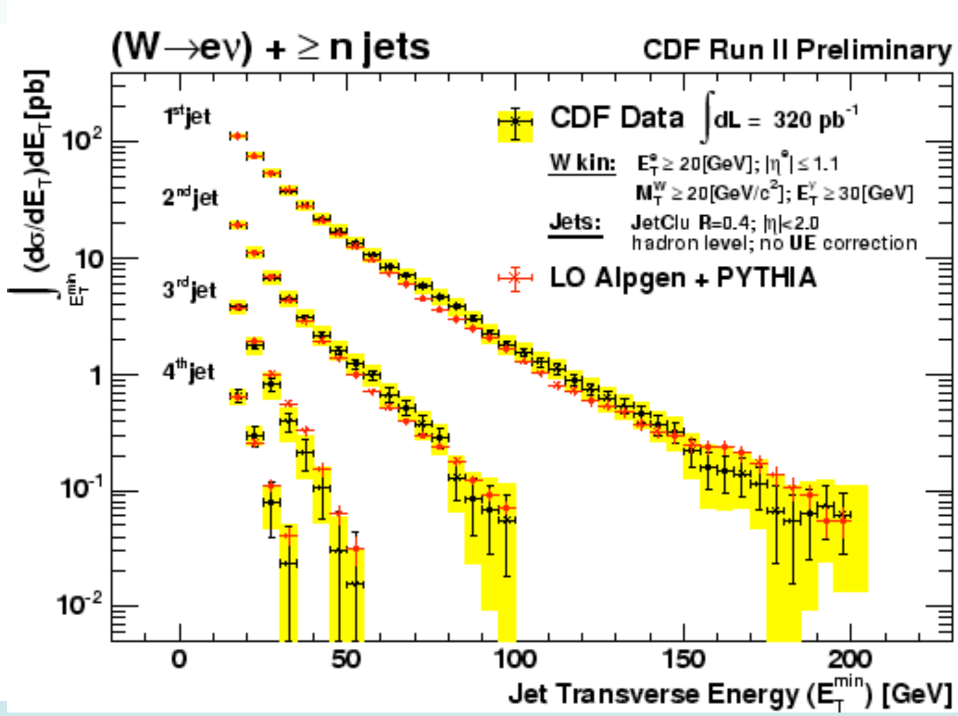
→ use shape of secondary vertex mass

W+jets results

Differential xsec wrt jet E_T in each of the 4 W+ n jet inclusive samples



Integrated xsec wrt jet E_T in each of the 4 W+ n jet inclusive samples

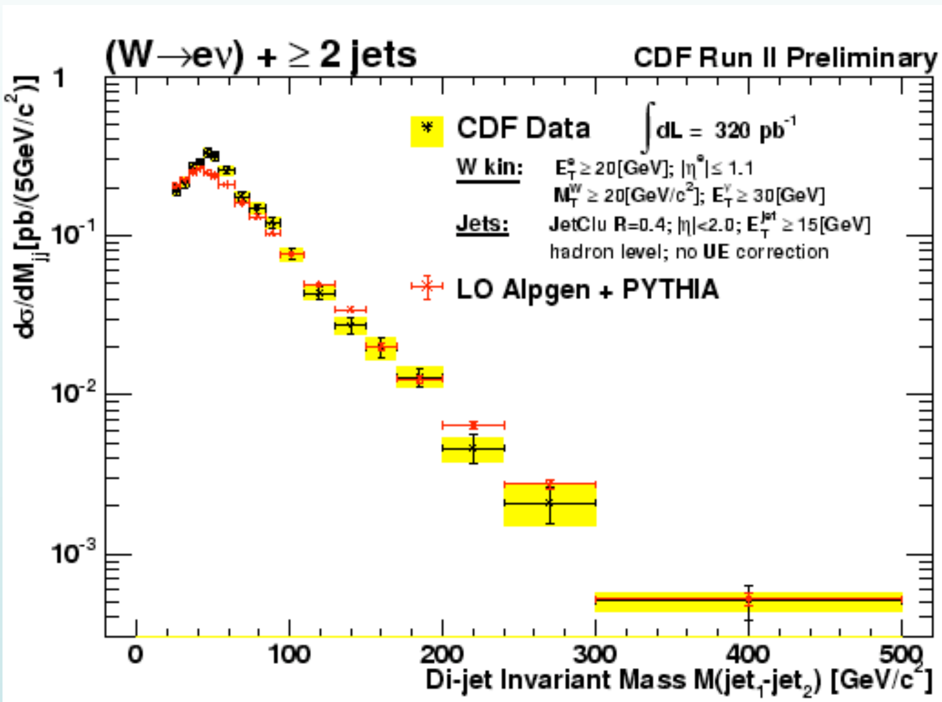


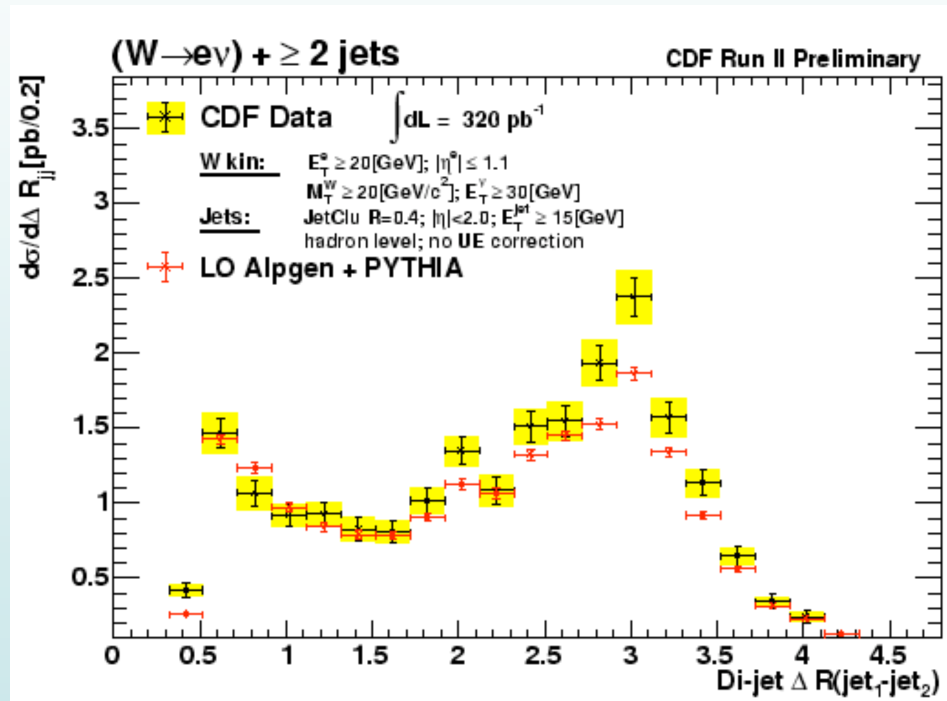
Caveat: this is not a full theory to data comparison. MC have been normalized to data inclusive cross section in each jet multiplicity sample!

W+jets results

Differential xsec wrt di-jet invariant mass in the W+ 2 jet inclusive samples

Differential xsec wrt di-jet ΔR in the W+ 2 jet inclusive samples



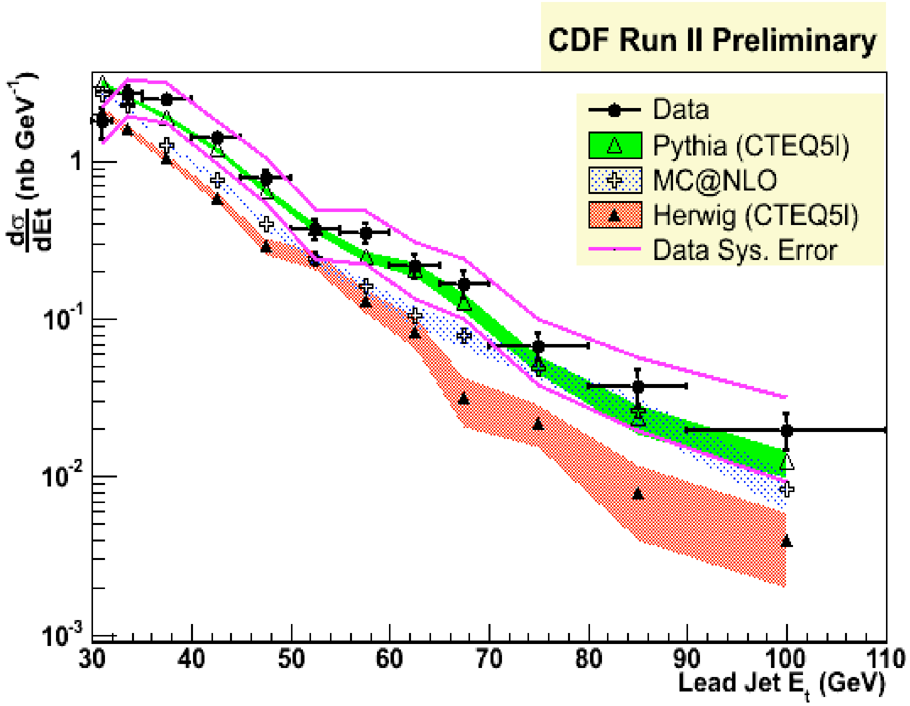


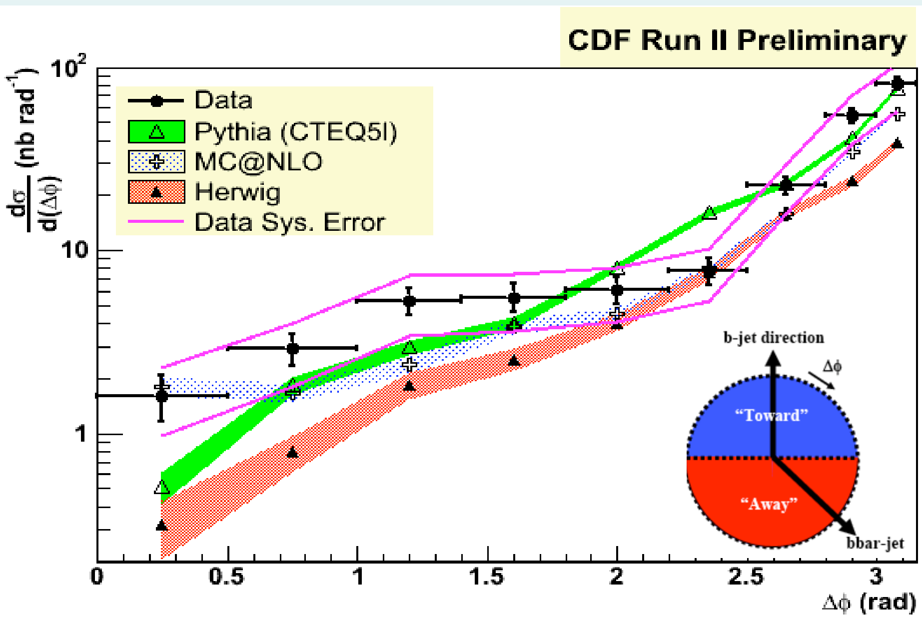
Caveat: this is not a full theory to data comparison. MC have been normalized to data inclusive cross section in each jet multiplicity sample!

bb jet correlation

- ✓ Cone based jets: R = 0.7, $|\eta^{jet}| < 1.2$
- ✓ E_T^{1st}>30GeV, E_T^{2st}>20GeV
- ✓ Reconstruct secondary vertex from B hadron decays (b-tagging)
- ✓ Shape of secondary vertex mass used to extract b-fraction from data

$$\sigma_{bb} = 34.5 \pm 1.8 \pm 10.5 \text{ nb}$$





PYTHIA Tune A CTEQ5L	38.7 ± 0.6 nb
HERWIG CTEQ5L	21.5 ± 0.7 nb
MC@NLO	28.5 ± 0.6 nb
MC@NLO + JIMMY	35.7 ± 2.0 nb

Relevant contribution from multiple parton interactions!!!